APPENDIX F

GROUNDWATER FLOW CONDITIONS

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GROUNDWATER FLOW CONDITIONS

Groundwater flow in the vicinity of the Expanded Study Area and Site R has been monitored routinely since 1983. Additional information on groundwater flow and aquifer characteristics of the three hydrogeologic zones within the unconsolidated aquifer was developed during RI activities in 1992. These activities included collecting water-level measurements under static conditions and conducting an aquifer test at Site R. This information was used to supplement previous data and to calibrate a three-dimensional groundwater flow model (Appendix H of the Site R RI Report). Section 1 discusses groundwater flow conditions; Section 2 provides a summary of the aquifer test; and Section 3 provides a discussion of groundwater discharge calculations.

1.0 GROUNDWATER FLOW

Section 1.1 provides a description of groundwater flow conditions based on data collected prior to December 1992. Section 1.2 discusses results of modeling performed to assess the impact of the 1993 Mississippi River flood on the groundwater system.

1.1 NORMAL RIVER STAGES

As discussed in Section 2.6 of the RI Report (Historical Groundwater Use and Flow Patterns), regional groundwater flow in the three hydrogeologic zones is to the west, towards the Mississippi River. Water levels measured on June 3, 1992 in the shallow, intermediate, and deep zones are shown on Figures 1, 2, and 3, respectively. These data are summarized in Table 1.

Figure 1 shows that a groundwater mound exists in the shallow zone at Site R. The existence of this mound has been previously documented in the RI work plan. It is apparently due to low permeability units beneath the area that reduce drainage rates from the shallow zone after periods of precipitation or high river stage. Groundwater flows to the east and south from the mound, but must eventually flow west toward the river. Historical data and the groundwater

model (Appendix H of the Site R RI report) indicate that the eastern flow reaches a stagnation point (where the eastward flow meets the regional westward flow) which is generally between Site R and the levee. Its exact location depends on the magnitude of the regional westward flow and river stage. At the stagnation point, water from the shallow zone flows downward into the intermediate zone. Water which flows south from the mound eventually turns to the west under the influence of the regional flow patterns.

Both the easterly and southerly flow from the mound are included in the model. The easterly flow is included in the intermediate zone estimate of groundwater discharge to the river. Wells screened in the intermediate zone adjacent to the river encounter this flow. Shallow wells along the river in the southern portion of Site R and in the Expanded Study Area encounter the southern flow.

Figures 2 and 3 show that groundwater flow in the intermediate and deep zones on June 3, 1992 was toward the river. Water-level data from well clusters screened in the intermediate and deep zones (GM-27B and GM-27C, P-8 and GM-56C, and GM-28B and GM-28C) indicates that there is an upward gradient from the deep zone to the intermediate zone (Table 1). This is to be expected because these wells are adjacent to the Mississippi River, which is a major groundwater discharge boundary. Groundwater flows from the lower portion of the aquifer up toward the river.

During periods of high river stage, when the river rises higher than the water table, gradients in the intermediate and deep zones are reversed. Flow in all three zones is toward the east, but eventually reaches a stagnation point where the eastward gradient equals the westward regional gradient. This "riverbank storage effect" can last from several days to a few weeks. The response of all three zones to varying river stages was demonstrated in hydrographs provided in the RI Work Plan (Geraghty & Miller 1990).

1.2 FLOOD CONDITIONS

In order to assess the impact of extreme conditions, such as those in the flood of 1993, a scenario which simulated even worse conditions was run on the model. A flood stage of 48 ft was assumed to last for 60 days. The flow field at the end of the 60-day period was then used to estimate the flow velocities to the east. The actual flood crest was 49.5 ft on August 1, 1993, and river levels dropped by 10 ft (to 39.5 ft) within two weeks.

The modeling results estimate that under the extreme conditions simulated, groundwater in the intermediate zone would travel approximately 6.5 ft/day. In the deep zone groundwater would travel approximately 8.3 ft/day. Water levels in the shallow zone did not reach equilibrium in the 60-day period modeled. Water-level measurements obtained from wells east of the flood wall on July 24, 1993 (when the river stage was 46.5 ft) were used to calculate a groundwater velocity of 0.06 ft/day in the shallow zone.

Within the actual groundwater flow environment, constituents dissolved in the groundwater would move more slowly than the predicted groundwater velocities because various factors such as adsorption and biodegradation can retard their movement. No retardation coefficients were considered in the modeled scenario.

2.0 AQUIFER TEST

An aquifer test was conducted at Site R to provide site-specific hydraulic characteristics necessary to calibrate the three-dimensional groundwater flow model for the area and to calculate concentrations of constituents discharging to the Mississippi River for use in the risk assessment. During June 15 through 19, 1992, a step-drawdown test, constant-rate aquifer test, and recovery test were conducted. The site-specific aquifer coefficients determined from this testing include transmissivity, hydraulic conductivity, and storage coefficient. A detailed discussion of the aquifer test results are provided in Appendix G (Groundwater Flow Conditions) of the Site R RI report.

3.0 GROUNDWATER DISCHARGE CALCULATIONS

As one of the first steps of the risk assessment, a list of chemicals of concern (COC) was selected for the groundwater at the Expanded Study Area. In order to complete the evaluation of risks associated with exposure to river water affected by the ground water, predicted concentrations of the COCs in the river were calculated. Geraghty & Miller used the groundwater model described in Appendix H of the Site R RI report and the concentrations of the COCs in the wells to complete these calculations.

Several steps were involved in the process. First, because the rate of groundwater discharge to the river changes with varying river stage, data were obtained from the U.S. Army Corps of Engineers (COE) which show the daily percent frequency of occurrence for every river stage on record in 1-ft increments, i.e., the percent of days in a given period that each river stage occurred. The data included the 130-year period from January 1861 to December 1991.

Using these data, a range of river stages was selected for the discharge calculations. The lower limit of this range was 374 ft above mean sea level (msl), the lowest river stage on record. The upper limit of the range was 410 ft above msl. Groundwater level data and the model indicate that the hydraulic gradient in the aquifer reverses above this level, so there would be no discharge to the river.

The model was used to predict the groundwater discharge to the river at each river stage in the range for Site R. A separate calculation was done for each of the three hydrogeologic zones. These predicted discharge rates at each river stage were then multiplied by the frequency of occurrence for that stage. These products were summed to obtain a weighted average daily discharge for each aquifer zone. This represents the average volume of ground water which flows into the river each day from each aquifer zone along the entire length of Site R (2,000 ft). The volume of average daily groundwater discharge along the western boundary of the southern portion of the Expanded Study Area was calculated as a percentage of the total volume of groundwater discharge for Site R. The river frontage at the Expanded Study Area is 150 ft, and

therefore, groundwater discharge at the Expanded Study Area was a percentage of 150 out of 2,000 ft of the Site R discharge from each zone.

To obtain the predicted concentration of each COC in the river, these daily loadings will be divided by the flow rate in the river. Both average exposure and reasonable maximum exposure (RME) scenarios will be considered in the risk assessment. Calculations of the river concentrations of each COC will be shown in the risk assessment.

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Table 1. Water-Level Elevations in Monitoring Wells, June 3, 1992, Monsanto Company, Sauget, Illinois.

Well No.	Measuring Point Elevation (1)	Depth to Water (2)	Water Level Elevation (1)
Shallow Wells			
B-21A	428.53	29.93	398.60
B-22A	428.16	28.79	399.37
B-24A	422.49	22.17	400.32
B-25A	428.47	30.95	397.52
B-26A	423.71	26.37	397.34
B-28A	423.04	25.25	397.79
B-29A	429.03	31.97	397.06
B-31B	421.68	28.45	393.23
P-6	421.78	24.92	396.86
P-7	421.82	22.96	398.86
P-14	424.36	24.93	399.43
GM-62A	425.75	31.99	393.76
GM-65A	424.11	32.66	391.45
GM-66A	422.73	27.79	394.94
Intermediate Wells			
GM-27B	426.04	36.63	389.41
GM-28B	423.88	34.15	389.73
B-21B	428.37	36.12	392.25
B-22B	428.16	37.55	390.61
B-23B	428.17	33.97	394.20
B-24B	422.28	31.70	390.58
B-24C	422.52	32.02	390.50
B-25B	427.35	34.84	392.51
B-26B	423.62	33.29	390.33
B-27B	425.83	34.26	391.57
B-28B	423.08	32.55	390.53
B-29B	429.06	36.69	392.37
B-30B	430.52	38.02	392.50
B-31C	421.88	28.70	393.18
P-1	423.11	33.18	389.93
P-2	423.15	33.26	389.89
P-3	423.43	33.27	390.16
P-4	421.82	31.70	390.12
P-5	422.12	32.31	389.81
P-8	421.79	32.02	389.77
P-9	423.14	33.38	389.76
P-10	423.43	33.19	390.24
P-11	422.30	32.68	389.62
P-12	423.75	34.45	389.30
P-13	424.32	34.90	389.42
GM-62B	426.16	32.42	393.74
GM-66B	423.20	34.05	389.15
TW-1	423.14	32.47	390.67
Deep Wells			
GM-27C	426.76	36.60	390.16
GM-28C	423.78	33.98	389.80
GM-55C	422.88	32.32	390.56
GM-56C	422.16	31.16	391.00
GM-57C	424.02	34.06	389.96
GM-62C	427.03	33.30	393.73
GM-66C	423.46	34.37	389.09
Bedrock Wells			
GM-106	424.82	29.73	395.09
B-102	423.84	31.74	392.10

(1) Elevation in feet above mean sea level.
(2) Depth to water in feet below measuring point.

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Figure 1 Water-Level Elevations in the Shallow Zone on 6-3-92.

Figure 2 " " " " " Intermediate Zone on 6-3-92

Figure 3 " " " " " Deep Zone on 6-3-9